SEMICLASSICAL INVESTIGATIONS OF LOW FREQUENCY, LONG RANGE ACOUSTIC PULSE PROPAGATION IN DEEP OCEAN ENVIRONMENTS

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LONG-TERM GOAL

Our long-term goal is to address the limits of feasiblity of underwater acoustic propagation models based on the geometric acoustics approximation. Accomplishing this goal will lead to an understanding of the limiting resolution of acoustic tomographic inversions for oceanic structure, whether using stochastic or deterministic methods.

SCIENTIFIC OBJECTIVES

A primary scientific objective of this work concerns relating dynamic ray stability to the observed intensity distribution of the acoustic wavefield for pulse propagation through the structured ocean waveguide at megameter ranges. Another scientific objective of this work is to understand the limitations of deterministic numerical ray tracing in realistic ocean environments.

APPROACH

We attack these problems by first investigating simplified ocean acoustic dynamical system models where known theoretical results can be utilized. A "stability exponent" distribution is derived as a function of the reception range. This distribution depends on the spectrum of sound speed fluctuations as well as the background sound speed profile. The cumulative probability of this distribution then determines what apportion of an initial distribution of rays will be marginally stable at the reception range. The next step is to semiclassically construct the wavefield and derive the distribution of intensity for broadband pulse propagation.

To understand the limits of deterministic ray tracing, we exploit Hamiltonian dynamics concepts developed by Greene [J. Math. Phys. **20**(6), June 1979]. Careful numerical simulations are performed, taking into consideration the interpolating scheme for the gridded sound speed environment.

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WORK COMPLETED

Using an idealized field of sound speed fluctuations and uniform backgound sound speed, we have derived an expression for the distribution of eigenvalues of the matrix which relates to the semiclassical amplitude contribution for a single ray. This distribution is found to be lognormal. The stability exponent distribution is then found to be Gaussian and asymptotically approaches a delta distribution with the inverse of the square root of the range.

It is important to note that although our theoretical work uses a highly idealized model where results based on the Markov limit in range can be applied, the theoretical arguments that lead to the stability exponent taking on a Gaussian distribution do not depend on the model. In this sense we consider our results as robust.

As for the limits of deterministic ray tracing, numerical investigations have been performed involving the sensitivity of a constructed time front due to perturbations of the environment (e.g. due to day to day evolution of a field of eddies). Even highly unstable rays are observed to be insensitive to perturbations in the environment in the sense that they still reside on the original time front. This work appears promising, and it will be continued in more detail during the following year. It is too preliminary to state anything further at this time.

RESULTS

Numerical results regarding the stability exponent distribution were reported at the 137th ASA meeting in Berlin. A manuscript describing the theoretical and numerical results is in preparation.

IMPACT/APPLICATION

The impact of the above work will be more fully realized after semiclassical treatments are utilized to infer the intensity distribution for broadband acoustic pulses. However, the results thus far are promising in that they indicate a measure for the apportion of nearly stable rays that could be useful for tomographic inversion. The source frequency and bandwidth will determine what scales of the ocean structure are relevant to incorporate in the numerical simulations, and this then determines the range dependence of the apportion of these nearly stable rays.

TRANSITIONS

None.

RELATED PROJECTS

This work is related to the data analysis effort of the North Pacific Pacific Acoustic Laboratory project led by P. Worcester and R. Spindel, and is a collaborative effort with S. Tomsovic and M. Brown.

REFERENCES

M. A. Wolfson, and F. Tappert, "Study of horizontal multipaths and ray chaos due to ocean mesoscale structure", J. Acoust. Soc. Am. , in press.